Globelics

PROVINCES, CITY-REGIONS, AND INNOVATION IN SOUTH AFRICA

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Ex ante: Mea culpa

The present paper is not the one I originally planned to write and submitted an abstract for. The two are related, albeit in ways that require some words of explanation lest I be suspected of conning my way into the conference.

I have been working on the determinants of regional innovation in South Africa since 2006 (Lorentzen 2007a,b, 2008). Due to the paucity of data on innovative activities in general and at a more disaggregated spatial scale in particular, this involved making new use of existing databases as well as building up new ones. With consolidation of the data I felt confident that it would be possible to move gradually from primarily descriptive to more propositional and finally to proper analytical work. Hence my abstract proposed to estimate a regional knowledge production function.

More precisely, my earlier results allowed for conjectures of regional versus sectoral determinants of innovative activities throughout the country. The paper I wanted to write aimed to take the analysis further by formally relating South Africa's knowledge infrastructure to technological achievements, in its course addressing the following questions:

- What increases in technological achievement can be attributed to increases in R&D expenditure and scientific output at the national level?
- What are the sectoral and geographic determinants behind different provincial efficiencies of this relationship?
- What are the threshold values below which R&D investments make no difference because S&T efforts require a minimum critical mass?

The analysis was to be based on a cross-sectional estimation of a function that for 2004 – the only year for which complete data were available – related changes in technological achievement to changes in industrial activity, R&D spending, scientific endeavour, the technology content of imports and exports, the governance system (i.e. provincial-level support), and human capital indicators such as the availability of post-graduate scientists etc. Unfortunately the estimations produced bizarre results that were impossible to make sense of. For example, in South Africa's technologically most advanced province of Gauteng, increases in R&D investments were *negatively* related to technological output. Normally these estimations are performed on panel data. But time series information was not available, thus severely limiting the number of observations and in view of the results barring, at least for the time being, this mode of inquiry.

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Not having perfect data is of course a bad reason to give up on regional analysis. It would likewise be unsatisfactory to wait for perfect data to emerge until the cows come home. The solution this paper adopts is to disaggregate provincial data yet further to the city-region level. The idea is to look for additional evidence at the urban scale in favour of the conjectures emerging from the region-level analysis. The result is very much a work in progress.

With apologies to the reviewers and the discussants.

Introduction

Regional and local innovation systems matter insofar spatial agglomeration, proximity, and inter-firm relationships contribute not necessarily all but important elements to the explanation why and how certain innovative activities take place. Since innovation is important for growth, it is apposite to look into (sub-)regional innovation systems and search for answers as to why some regions falter while others power ahead, even though they belong to the same country and are therefore subject to at least some of the same opportunities and constraints.

Until relatively late into the past century, economic theory suggested that in the long run the rate of technological change would converge because due to the public-good character of technology, all firms would eventually face the same technological opportunities (Solow 1956). More realistic perspectives subsequently argued that technology is a private good and that not all places are equally in a position to make use of innovations, prominently because they do not have the requisite human capital. When successful locations continue to invest in education and training and smartly manage to avoid the diminishing returns due to congestion, rising costs, and so forth, they are able to sustain and even grow the gap that separates them from the laggards (Krugman 1991, Romer 1990, Werker and Athreye 2004). In reality, technology is neither completely public nor private. When a local firm picks up an idea from the subsidiary of a foreign multinational, the latter no longer enjoys monopoly rents from superior technology. These spill-over effects may well be much more important at the regional than at the national level (Howell 2005).

Evidence from areas of the world with good regional data such as the EU or the US unambiguously shows wide income disparities between regions over time. But the dynamics of regional growth are understood only incompletely, despite a substantial body of empirical work consisting of spatial econometrics, cross-sectional convergence studies, investigations of clusters, and of spatial patterns of patents, R&D investments, and so forth. Advances might come from theoretical models of spatial growth that incorporate richer microeconomic foundations than Krugman's new economic geography, and from systematic empirical analyses of datasets that contain information about individual firms (Cheshire and Malecki 2004). It is clearly imperative to understand absorptive capacities and technological upgrading – what goes on at the firm level – in the context of the interaction that may or may not happen at the regional level. For example, with large economies of scale and scope, firms should benefit more from cluster effects, much like they could compensate the high transaction costs characterising sectors with rapid technical change through joint action. Hence inter-industry differences in technology and transaction costs may explain why some regions possess collective institutional arrangements that help the innovative activities of their firms. In other words there is a relationship between the structure of innovation systems and the modes of coordination of system elements (Antonelli and Quéré 2002, Caniëls and Romijn 2003a).

The paper first reviews the literature on the role of proximity for economic development. It then develops conjectures about South Africa's regional innovation systems on the basis of apparent correspondences between productive and knowledge activities in four provinces (Eastern Cape, Gauteng, KwaZulu-Natal, Western Cape) that between them span the width of technological achievement in the country. It further aims to derive insights on the knowledge economy in four city-regions (Nelson Mandela Metropole, Gauteng global city region, eThekwini/Pietermaritzburg, Cape Town) from what we know about possible relationships between knowledge producers and users in the above four provinces of which the city-regions are part. The focus is on the interaction between knowledge (the pursuit and use of R&D, science, and technological innovations) and the real economy. The spatial character of the knowledge economy is probed by relating input (R&D) to output (publications and patents) measures, as well as the production (patents originating) and the use (patents absorbed) dimension of technological advance. This is undertaken at the lowest possible level of disaggregation of sectors and research fields. The conclusion suggests how to take this work further.

The role of proximity for economic development

One might usefully pose the question why an innovation happens in a particular location in the first place or, more generally, why the geography of innovation has been and continues to be rather concentrated (see Simmie 2005 for a useful survey of the literature). Answers to these questions have changed over time. Schumpeter argued that entrepreneurs in small companies recognise the value of an invention and mobilise the resources to turn them into innovations (1939). Marshall added the benefit of externalities resulting from the concentration of firms specialised in similar products (1890). Perroux (1950) followed up with his work on growth poles, and Vernon (1966) with product life cycles.

But from the 1980s the apparent contradiction between space on the one hand and globalisation on the other needed addressing. Why would a particular location continue to matter if almost all production became either mobile or expendable? A then influential explanation argued that both international competition and rapidly changing customer demand required firms to become more flexible which they did by de-verticalising their operations, creating smaller specialised firms in their wake. These in turn would form networks and agglomerate because they relied on proximity to organise the supply chain (Piore and Sabel 1984, Storper 1997). This argument, along with much related work on clusters and industrial districts, has been criticised, among other things, for generalising from a few cases and for mixing a fair amount of wishful thinking with analysis (see, for example, Markusen 1999).

A different explanation is that innovation happens where multinational firms (MNCs) locate their R&D activity. Small firms may be able to cope with the accelerating pace of technical change by hooking into value chains run by MNCs, thus reinforcing spatial concentrations of innovative activity. Simmie (2005) criticised that key concepts used in this literature are difficult to operationalise, leading to no shortage of empirical work but to partially underspecified analyses.

Proximity does not exclusively exist in a geographic sense. It has other dimensions – institutional, organisational, cognitive, and social – all of which may help solve coordination problems. When used uncritically, it merely presupposes that "being close" is somehow a good thing. To be sure, some cognitive proximity is essential for learning to take place. If one actor has no clue what the other is talking about, interaction is pointless. Too much proximity, however, may be detrimental for two actors with the exact same set of knowledge have little to learn from one another. Hence, keeping only one's own company may lead to technological cul-de-sacs. The centrality afforded space in the discussion of innovation raises the question how important geographic proximity is relative to the other dimensions. Geographic and cognitive proximity ("*I live next door to you and we speak the same language*.") may be sufficient for learning but the organisational, institutional, and social dimensions ("*We've got something to talk about and have the incentives and means to organise this conversation although – or perhaps because – we live far apart*.") may substitute for physical closeness (Boschma 2005).

Empirical work is much messier than these neat theoretical considerations. Depending on which study one looks at or which author one follows, proximity either matters (e.g. Asheim and Coenen 2005, Audretsch and Lehmann 2005, Capello and Faggian 2005, Carrillo 2004, Greunz 2003, Porter 2003, Rondé and Hussler 2005) or does not (e.g. Caniëls and Romijn 2003, Helmsing 2001, Niosi and Zhegu 2005, Simmie 2004, Wolfe and Gertler 2004). Since most studies apply a particular question to a unique data set or case, this is not surprising: what you see is what you get. Short of systematising the substantial body of empirical analyses, the field will remain in a somewhat inconclusive and partially contradictory state.

What is also somewhat unclear is the merits of diversity versus specialisation in an agglomeration. The advantages of specialisation are associated with Marshall who derived his "industrial atmosphere" from people doing the same thing and realising the benefits of local monopoly power, while Jacobs lent his name to externalities resulting from local competition for ideas of smart employees whose opportunity to test them is related to the number of firms in the area. In an analysis of a sample of Dutch firms, van der Panne (2004) finds that specialised local production structures favour innovative activity. The explanation is that intra-industry spill-overs are more prevalent than inter-industry spill-overs. For R&D-intensive and small firms, knowledge spill-overs have limited geographical reach which is why proximity matters. In other words, increased levels of local production structure diversification do not favour local innovativeness.

Using a larger dataset covering firms in Europe, Greunz (2004) arrives at a more nuanced conclusion. On average, patenting activity in Europe is influenced by both specialisation and diversity externalities, but diversity is more important than specialisation. In metropolitan areas, where of course much innovation is concentrated, innovation is on average a result of diversity spill-overs. But high-tech innovations in high-density regions depend exclusively on diversity externalities. Hence the import of diversity increases with the technological intensity of an industrial activity. In turn, she finds that for sectors with lower technological intensities, specialisation externalities remain important and their impact on innovation increases with decreasing technological intensities.

Lim (2004) takes this a step further by probing the kind and origin of knowledge spill-overs in their impact on innovative activities in metropolitan areas in the US. Unlike Greunz (2004), he finds that both specialisation and diversity externalities matter for high-tech industries. Innovative activity is further affected by the level of innovativeness in neighbouring metropolitan areas but only for high-tech diversity externalities. Hence high-tech specialisation externalities are more localised than high-tech diversity externalities; this importantly qualifies the ways in which geographic proximity matters.

In sum, in some circumstances co-location does affect innovative activities, in others it does not. This is a pretty inconclusive state of our understanding of these issues (Iammarino and McCann 2006) and affects the quality of policy advice. The most fundamental question of course is whether and how to address regional growth disparities. To the extent that technology is relatively easily appropriable lagging regions can simply free-ride on the achievements of the core where R&D investment should therefore concentrate. But quite apart from the fact that absorbing technology is rarely easy, core areas may suffer from decreasing returns, congestion, and so on. Combined with the political need to stem brain drain and foster spin-offs and a commitment, in principle, to convergence, a rationale therefore exists for both private and public investment in backward areas.

Yet this needs to be qualified because activities in the core need not necessarily run into increasing returns. In addition, thresholds in terms of the quality of the workforce, a given concentration of R&D, and the quality of human capital see to it that R&D activities cluster in metropolitan areas. In this case, knowledge must be diffused to the hinterland, a process whose feasibility and cost depend prominently on the absorptive capacities of the local firms. Below a certain threshold, no amount of investment will bear fruit and spill-overs will not materialise (Rodríguez-Pose 2001). Greunz (2004) argues that policy in favour of a certain activity or technology should only happen once clarity exists with respect to the regional industrial organisation and composition. In laggard regions, most may be gained from supporting activities that increase the specialisation of the area because it is only from a certain level of development that diversity externalities kick in.

Orlando and Verba (2005) deal with the benefits that relatively populous regions generate by way of thick markets and knowledge spill-overs, and ask whether large populations are per se a prerequisite for innovation. This would be bad news for peripheral and rural regions and not leave much scope for policy. They study patent activity in 2,295 geographical areas of the US from 1990 to 1999 and find that population density matters more for innovations in newly emerging than for those in mature technologies. While thick markets and knowledge spill-overs somewhat mitigate uncertainty in areas of rapid technical change, the incremental innovation in mature sectors is easier to plan and makes it feasible to avoid the high costs of big-city locations and instead operate from the middle of nowhere. In short, the location of innovation depends on technological maturity. Therefore, policies that mitigate the distance from the benefits associated with metropolitan areas – such as high-quality communication and transport infrastructure – can render less populous places attractive for innovators in mature technological fields.

Crescenzi (2005) develops an analytical model of regional growth based on the NIS literature and tests it on data from all EU member states. He finds that geographic accessibility matters in that it minimises risk, suggests a higher probability of getting in touch with new ideas, allows for easier outward networking, and benefits from a wider diversity. All these factors make innovative efforts more productive. Of course, policy can do very little about geography per se. Indeed, this first finding militates, for efficiency reasons, against investments in laggard regions. But his second result is that a high level of human capital accumulation leads to a more productive increase in innovative effort. Thus, education matters insofar it contributes to economic growth both directly and indirectly. The implication for policy is, quite simply, to invest in people.

The creation of a skilled production and technical labour force, together with the overall effort to exploit foreign sources of technology, and the degree of competition and macroeconomic stability influence how well a regional innovation system can act as a vehicle for inbound technology transfer. Insofar as no two regions are identical, this then supports the rationale for regional innovation policy complementing its national counterpart (Carlsson 2006, see also Amin 1998 for a sceptical view).

Tödtling and Trippl (2005) also caution against a one-size-fits-all approach to policy. They differentiate central, peripheral and old industrial regions, each facing different kinds of problems. In peripheral regions with small firms in traditional sectors, no or poorly developed linkages, and no support institutions, the goal must be to generate catching up learning through the attraction of outside companies and giving them incentives to link with local firms. In old industrial regions suffering from lock-in, policy should focus on organisational upgrading, technological diversification, and reorganisation of the whole institutional set-up. In metropolitan regions with problems of fragmentation, the goal is to foster the growth of internationally linked knowledge-intensive clusters.

Over the past decade or so city-regions have come to enjoy more attention in spatial economic analysis. They reportedly facilitate and coordinate the interaction between local spaces and the global economy. Since they are normally more contained than regions – or, in this case, provinces – they lend themselves to an empirical verification of the benefits of specialisation and diversity discussed above. And since they have a relationship with their surrounding area, questions of uneven development also matter (Sassen 2001, Scott 2001). But this literature has not really tackled innovation or the knowledge economy in a systematic way even though city-regions are obviously part of regional and national innovation systems.

In the absence of fool-proof theoretical results, the analysis of what determines innovative activities in South Africa at the subnational level then becomes primarily an empirical question. This is the topic of the next section.

Provincial specialisation maps

Weighted provincial specialisation indices for productive activity, R&D expenditure, scientific publications, and patents form the core of the analysis. A province is specialised in a particular activity, if it pursues the activity above the national average *and* accounts for a minimum of 20 per cent of national output.

Figures 1-4 show what goes on where across the country. The discussion is limited to the four provinces that host the city-regions. Regarding the spatial distribution of economic activity, the Eastern Cape has no specialisation, the Western Cape two, KwaZulu Natal three, and Gauteng four (see Figure 1). When secondary activities are disaggregated, Eastern Cape and Western Cape contribute with specialisations in transport equipment, reflecting the automobile industry around Buffalo City and Nelson Mandela Metropole, and food and beverages as well as textiles in the Cape. Mainstays of KZN manufacturing with national importance are food, beverages, and tobacco; textiles, clothing, and leather goods; wood and paper; publishing and printing; and furniture. Gauteng is the only province with high-tech manufacturing; next to non-metal mineral products, metals and metal products, and furniture, it is specialised in electrical machinery and instruments.

[FIGURES 1-4 HERE]

Gauteng is therefore the province with the highest degree of specialisation and diversity of economic activity. The country's main metropolitan region is well poised to exploit relationships between technological neighbours – for example producers of metal products and of machinery or instruments, respectively – and harness diversity for innovative output. Importantly, it is also specialised in low-tech activities such as furniture so both specialisation and diversity externalities can come to play. By contrast, the weak presence of relevant industrial specialisations in the Eastern Cape is reason for concern. Spill-overs from the centre or from outside investors will only materialise with a minimum level of absorptive capacities that, in turn, depend on some degree of specialisation for externalities to materialise.

In 2004, 61 per cent of R&D investment took place in Gauteng, 14 per cent in the Western Cape, nine per cent in KwaZulu-Natal, and two to three per cent in the Eastern Cape (see Figure 2). The centre of R&D investments is Gauteng with a very wide sectoral distribution ranging from agriculture to professional services, followed by the Western Cape and KwaZulu-Natal. Perhaps surprisingly in view of KZN's much more blue-collar industrial structure, by comparison it is the Western Cape that attracts more investments in manufacturing (see Figure 2). When classified by research fields, Gauteng leads with 55 per cent, followed by Western Cape (17%), KwaZulu-Natal (10%), and Eastern Cape (4%). Gauteng and Western Cape are specialised in a wide range of research fields.

In the spatial distribution of scientific publications, Gauteng leads with 16 specialisations (including all national output in neurosciences), followed by Western Cape with 14 (including total national output in medical biochemistry), and KwaZulu-Natal with six (including total national output in environmental engineering). The Eastern Cape has no specialisation at all (see Figure 3). Science output is therefore largely concentrated in three provinces. Since empirical evidence shows that R&D-intensive universities in R&D-intensive regions may lead to more technological activity, it is these three provinces that primarily merit an investigation of regional dynamics, but not the others.

In 2004, Gauteng led patent applications with 57 per cent, followed by Western Cape and KwaZulu-Natal with about 13 per cent each, and Eastern Cape (2%) (see Figure 4). Both Gauteng and Western Cape have specialisations in primary activities, but the bulk lies in manufacturing. The only other province with specialisations is KwaZulu-Natal. Hence technological competence in the country is much more concentrated than economic activity, R&D investments, or scientific output, and regional dynamics may be at the forefront of innovative activities in Gauteng and Western Cape.

Provincial interaction maps

The regional presence of knowledge economy dynamics can make itself felt to the extent that predominant sector activities co-exist with high R&D or technological intensity in those same sectors. Technological intensity can have one of two or both meanings, namely an intensive production of new knowledge (reflected in patent applications) or an intensive use of new knowledge (reflected in making use of new knowledge through licensing and so forth). To be sure, it is not possible to attribute causality to the observed co-existence. In other words, just because, say, KZN concomitantly hosts a lot of leather production, along with R&D in textiles, clothing and leather goods, and patents related to tanning and dressing of leather coming out of and being used by this sector, does not necessarily mean that the underlying production function is knowledge intensive. But it strongly suggests that this may indeed be the case which then warrants further investigation. By implication, if no such correspondences exist, it is safe to conclude that regional innovation dynamics do not play an important role in the provincial industrial profile.

Figure 5 (and, in greater detail, Table 1) shows that such correspondences exist rather sparsely. In Gauteng, they concern basic metals, select electrical components, a variety of instruments, and business services. In KZN, they exist for certain agricultural activities, the aforementioned processing of leather, paper and related products including publishing and printing. In the Western Cape, they are limited to a few activities in agriculture and forestry. They do not exist at all in the Eastern Cape.

[FIGURE 5, TABLE 1]

This suggests that the most important determinants of innovative activities are unlikely to be located at the provincial level, except in those few areas mentioned above. This means that a firm in the Eastern Cape is not more likely to benefit from knowledge-intensive activities in its immediate neighbourhood than those taking place in Gauteng and the Western Cape or perhaps KZN, but probably less, provided appropriate transfer opportunities exist.

The sparse linkages between sectoral, R&D, and technological specialisation further suggest that the local availability of knowledge is perhaps not commensurate with the technological demands of firms. Firms would then seek external sources of knowledge abroad in order to make up for the gap. This underlines the importance of linkages with foreign sources of knowledge for which city-regions might act as facilitating nodes.

The investments into R&D recorded here only reflect business sector activity. Therefore, if a province is specialised in the same research fields in R&D investments as it is in scientific output, one can hypothesise linkages between university and industry. Their existence would have to be shown through more detailed analyses, but such a situation is obviously different from one where firms pursue R&D in one set of fields while universities produce science in a completely different set. International literature shows that under certain circumstances university-industry linkages are beneficial to regional growth which is why it is important to understand the dynamics of this relationship.

A comparison of Figures 2 and 3 shows that R&D investment indices are much more concentrated than publications indices. Hence scientific capabilities exist at the regional level even in the absence of concentrated R&D spending. The “bang” is spatially concentrated in the country’s two most advanced provinces, Gauteng and the Western Cape. This is especially the case for the engineering disciplines in Gauteng (see Figure 6 and, for more detail, Table 2).[2]

[FIGURE 6, TABLE 2]

When investments in R&D in specific industrial activities co-exist with the production and use of patents in those same sectors, the existence of regional linkages between firms in the same or even across value chains is a distinct possibility. Again, the existence of correlation is no proof of

[2] It would be interesting to investigate if technological upgrading in those sectors based on engineering disciplines where change tends to be incremental is mostly localised in the sense that learning takes place within existing specialisations, while those sectors based on analytical, science-driven knowledge, such as health, make use of university-industry linkages (UILs) to produce new knowledge. This could suggest that UILs are relatively more important in the Western Cape – due to its relatively higher concentration in natural and health sciences – than in Gauteng with its premium on engineering competences.

causality but a good reason to investigate the exact nature of the hypothesised relationship further. Figure 7 shows that in Gauteng these correspondences exist for a rather broad range of sectoral activity, spanning primary (e.g. mining), secondary (e.g. precision instruments), and tertiary activities (professional services), both high- and medium-tech. In KZN the correspondence exists for one activity in each sector, while the Western Cape falls somewhere in between these two provinces. What is interesting about the Western Cape is that it has the highest absolute number of correspondences where a specialisation in R&D investments is accompanied jointly by specialisations in patent production and use (see Figure 8). This suggests that there might be more unintended spill-overs or even intended knowledge sharing at play. In other words the Western Cape is not the most important producer of new knowledge, but its most effective user.

[FIGURES 7, 8]

The existence, nature, and impact of spill-overs are among the most researched topics in technology studies. The same is true for the intended transfer of technology. The data allow to explore whether the patenting profile of a province suggests that it predominantly produces technology, absorbs technology, or – if both – does so in cognate economic activities. The expectation of course is that lagging provinces are, if anything, technology users while more advanced provinces probably do both. But a province might well turn out a set of patents that emanate from a range of industrial sectors whose firms are not particularly avid technology users. By contrast, if patents are produced and absorbed in the same sectors – for example by lead firms who then license them to laggard firms – one would be justified in probing the role of geographic proximity, and here especially the role of city-regions, in bringing such processes about.

Figure 9, when compared with Figure 4, shows that the concomitant existence of knowledge production and use in the same sectors is present only in a few activities in Gauteng and KZN. The situation is different in the Western Cape where with the exception of textiles all other technology-producing sectors face a cognate sector of use. Therefore geographic proximity does not appear to play a big role in South Africa, except in the Western Cape, where it appears to co-exist with sectoral dynamics.

[FIGURE 9]

Preliminary conclusions

The analysis suggests that regional or local innovation systems possibly exist in Gauteng and Western Cape, and possibly in KZN, but not in the Eastern Cape or anywhere else in the country. Although innovative activities do occur elsewhere, they do on the basis of the data reviewed here not appear to result from any systemic interactions at the local or provincial level, if only because in most cases there is no activity to interact with. More precisely, Gauteng seems to exploit diversified knowledge industries; Western Cape appears to be the province where regional and sectoral dynamics are especially important; what exactly goes on in KZN is hard to say.

This raises the following question. If Gauteng and Western Cape do in fact exhibit regional innovation dynamics, what determines them? Is it large economies of scale and scope, superior infrastructure, and a high demand for innovation that induce firms to move there and, once settled, do they stay because they somehow avoid running into diminishing returns and because government reduces transaction costs? Or, more prosaically, do firms enjoy agglomeration advantages and the benefits of joint action in dealing with technological change?

Gauteng, the province where most innovative activity in South Africa takes place, is a good case to examine the respective roles of specialisation and diversity externalities. What should be studied is not just which matters more on average, but whether the type of externalities is sector specific in the sense that the import of diversity increases with increasing technological sophistication. We also need to understand how localised either type of externalities is because this influences the scope of cross-provincial spill-overs and intended knowledge transfers or, put differently, because it suggests both opportunities for and constraints to "nationalising" the results of successful regional innovation activities.

The Western Cape has a much broader R&D than industrial profile, contrary to the rest of the country. It is also the most important producer of science and exploits technological information across a wide range of industrial activities, including from outside the province. What we do not know is how much of the resulting innovative activity is due to geographic proximity, sectoral dynamics, foreign technology, or a combination thereof. The answer to these questions will throw light on the feasibility and desirability of regional industrial policy and on the scope for cross-provincial spill-overs and international technology transfer.

The next step

In order to begin to address the research questions raised above, it is imperative to enrich the data set used here. We are looking for information that distinguishes Gauteng and the Western Cape from the other provinces and that, possibly, differentiates between these two locations. This can be done at two spatial scales, namely the provincial level and then the more disaggregated and thus hopefully more precise city-region level. Since interactions between producers and users of knowledge rely on warm bodies, the information required is about the innovation system, education, and human capital in the provinces under investigation. A first take is provided in Table 3 which largely follows the logic of the Knowledge Assessment Matrix developed by the World Bank.

[TABLE 3]

The information in Table 3 shows that Gauteng and the Western Cape are more dynamic and more highly developed provinces than the rest of the country. Where they differ most is in R&D investment and the highly skilled workforce. This corresponds with much higher scientific and technological output. They are also much more "turned on" (computers) and "tuned in" (internet access). By contrast, they do not enrol a higher share of the population in secondary and tertiary education. Therefore, differences in the innovation system and in information infrastructure appear to be related to differences in performances, while mere education enrolment does not.

At the next level of spatial disaggregation, one would expect that city-regions outperform their regional hinterland because economic and innovative activities tend to be concentrated in urban areas. Table 4 shows that this is indeed largely the case. The exception is the Gauteng Global City-Region whose demarcation extends beyond Gauteng Province, thus taking in less developed parts of the adjacent provinces of the Free State and Mpumalanga. High-growth spaces are magnets for in-migration (measured here by the increase in the economically active population and dependency ratios) but do not necessarily create jobs at a higher rate. One would also expect that there is less variance in city-region than in provincial performance. This, too, is borne out by the data. In terms of human capital, highly skilled people are scarce across the country, and no urban agglomeration bucks this trend. But there are differences in educational achievement. While the Western Cape and Gauteng overall send a lower proportion of the population to secondary and tertiary education institutions, the graduation rates of their metropoles are significantly higher. This implies that education per se does not matter; only high-quality education that sees students through to completion makes a difference.

[TABLE 4]

One would further expect that world-class technological output is concentrated in the urban areas. This is indeed the case in the Eastern Cape and Gauteng where patent activity is at its highest in the Nelson Mandela Metropole and in Johannesburg/Pretoria, respectively. But it is interestingly not the case in KwaZulu-Natal and especially in the Western Cape where technological activity appears to be much less dependent on the respective metropoles. For the Western Cape, this information reinforces the above finding that the province appears to host regional innovation dynamics. In other words, the effect of the high concentration of knowledge workers in Cape Town is not limited to the city-region but extends to the province more generally. The same is not the case for Gauteng where innovative activity appears much more limited to the metropoles. Therefore, the Western Cape innovation system appears to be spatially more diffused than the one in Gauteng.

This still leaves a long way to go before more is known about the determinants of innovation at a subnational scale. In the absence of national panel data on innovation, the most promising avenue might be to study knowledge flows systematically in their spatial context. For the Western Cape, this could focus on UILs in the context of sectoral analyses; for Gauteng, on inter-industry linkages. But even that would bring us only marginally closer to testing the many propositions advanced in the literature review.

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Figure 1

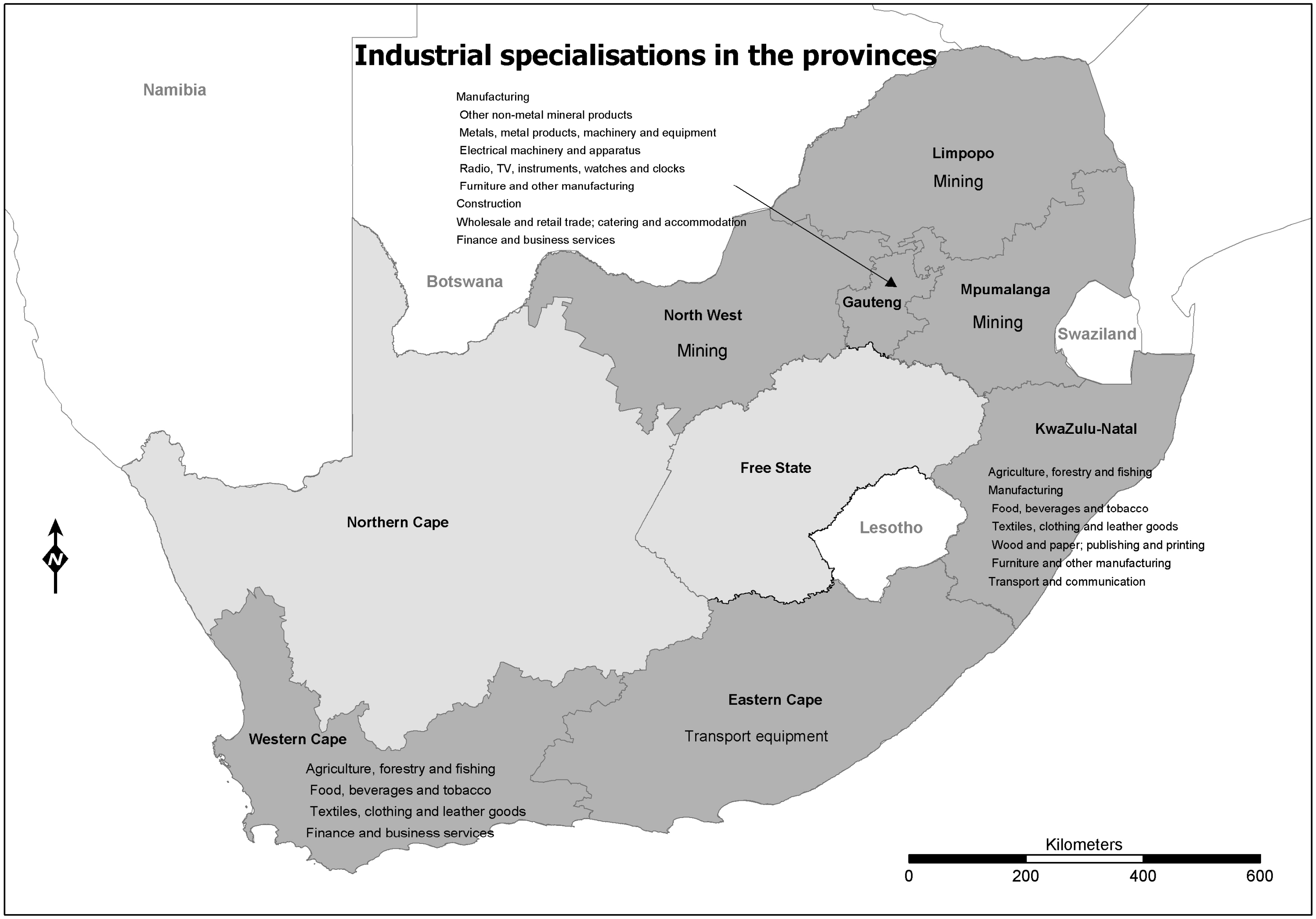
Industrial specialisations in the provinces
Namibia
Botswana
Manufacturing
Other non-metal mineral products
Metals, metal products, machinery and equipment
Electrical machinery and apparatus
Radio, TV, instruments, watches and clocks
Furniture and other manufacturing
Construction
Wholesale and retail trade; catering and accommodation
Finance and business services
Limpopo
Mining
Gauteng
Mpumalanga
Mining
North West
Mining
Swaziland
KwaZulu-Natal
Agriculture, forestry and fishing
Manufacturing
Food, beverages and tobacco
Textiles, clothing and leather goods
Wood and paper; publishing and printing
Furniture and other manufacturing
Transport and communication
Free State
Lesotho
Northern Cape
N
Eastern Cape
Transport equipment
Western Cape
Agriculture, forestry and fishing
Food, beverages and tobacco
Textiles, clothing and leather goods
Finance and business services
Kilometers
0
200
400
600

Figure 2


R&D specialisations in the provinces
Namibia
Botswana
Swaziland
Lesotho
Growing of fruit, nuts, beverage and spice crops
Mining of uranium and thorium ores
Mining of metal ores
Other mining and quarrying
Publishing, printing and reproduction of recorded media
Manufacture: paints, varnishes & similar coatings, printing ink &mastics
Manufacture: other non-metallic mineral products
Manufacture: basic metals
Manufacture: basic precious and non-ferrous metals
Casting of non-ferrous metals
Manufacture: machinery and equipment n.e.c.
Manufacture: electrical machinery and apparatus n.e.c.
Manufacture: insulated wire and cable
Manufacture: medical appliances & instruments & appliances
Manufacture: instruments & appliances except industrial process control
Manufacture: optical instruments & photographic equipment
Manufacture: aircraft and spacecraft
Manufacture: furniture; manufacturing n.e.c.
Collection, purification and distribution of water
Construction
Sale, maintenance and repair of motor vehicles & motorcycles
Wholesale trade and commission trade
Transport, storage and communications
Land transport; transport via pipelines
Air transport
Supporting & auxiliary transport activities; activities of travel agencies
Post and courier activities
Telecommunications
Financial intermediation, except insurance and pension funding
Activities auxiliary to financial intermediation
Real estate, renting and business activities
Computer: Data processing
Computer: Data base activities
Computer: Maintenance & repair of office, etc machinery
Research and development
Architectural, engineering and other technical activities
Business activities n.e.c.
Public administration and defence; compulsory social security
Limpopo
Mining & quarrying
Mpumalanga
Growing of cereals & other crops n.e.c.
Mining & quarrying
Mining of coal & lignite; extraction of peat
Extraction of crude petroleum & natural gas, etc
Manufacture of paper and paper products
Health and social work
North West
Mining of uranium & thorium ores
Manufacture of basic chemicals
Health and social work
Gauteng
Free State
Mining of coal and lignite; extraction of peat
Extraction of crude petroleum and natural gas
Manufacture coke, refined petroleum products & nuclear fuel
Chemicals and chemical products
Railway and tramway locomotives & rolling stock
KwaZulu-Natal
Growing of cereals and other crops n.e.c.
Forestry, logging and related service activities
Manufacture:food products and beverages
Manufacture: textiles
Manufacture: wood & of products of wood & cork
Manufacture: basic iron and steel
Manufacture: fabricated metal products
Manufacture: television & radio receivers
Manufacture: industrial process control equipment
Manufacture: other transport equipment
Collection, purification and distribution of water
Retail trade, repair of personal & household goods
Water transport
Computer: Software consultancy & supply
Advertising
Education
Other service activities
Northern Cape
Growing of vegetables, horticultural specialties & nursery products
Fishing, operation of fish hatcheries and fish farms
Manufacture: food products & beverages
Manufacture: textiles
Publishing, printing and reproduction of recorded media
Manufacture: pesticides and other agro-chemical products
Manufacture: rubber and plastics products
Manufacture: machinery and equipment n.e.c.
Manufacture: electrical machinery and apparatus n.e.c.
Manufacture: electronic valves & tubes, etc
Manufacture: television & radio transmitters, etc
Manufacture: medical & surgical equipment, etc
Manufacture: instruments & appliances, etc
Manufacture: aircraft and spacecraft
Manufacture: transport equipment n.e.c.
Wholesale and retail trade; repair of motor vehicles, etc
Retail trade, except of motor vehicles and motorcycles, etc
Land transport; transport via pipelines
Water transport
Air transport
Financial intermediation, except insurance and pension funding
Insurance and pension funding, except compulsory social security
Other business activities: Legal, accounting, book-keeping, etc
Advertising
Public administration and defence; compulsory social security
Health and social work
Western Cape
Eastern Cape
Manufacture paper and paper products
Manufacture motor vehicles, etc
Water transport
Advertising
N
Kilometers
0
200
400
600

Figure 3

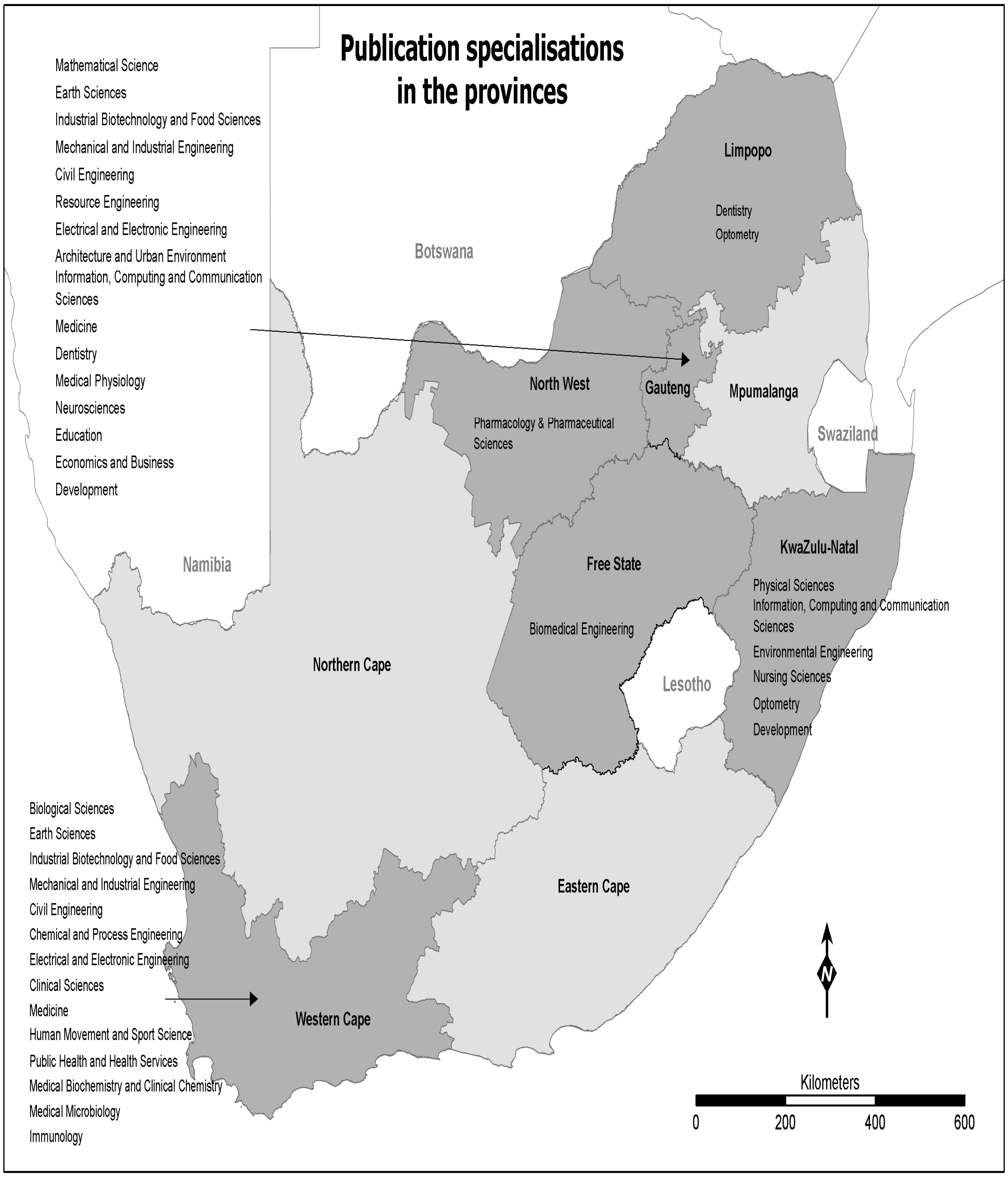
Publication specialisations
in the provinces
Mathematical Science
Earth Sciences
Industrial Biotechnology and Food Sciences
Mechanical and Industrial Engineering
Civil Engineering
Resource Engineering
Electrical and Electronic Engineering
Architecture and Urban Environment
Information, Computing and Communication Sciences
Medicine
Dentistry
Medical Physiology
Neurosciences
Education
Economics and Business
Development
Botswana
Limpopo
Dentistry
Optometry
North West
Pharmacology & Pharmaceutical Sciences
Gauteng
Mpumalanga
Swaziland
Namibia
KwaZulu-Natal
Physical Sciences
Information, Computing and Communication Sciences
Environmental Engineering
Nursing Sciences
Optometry
Development
Free State
Biomedical Engineering
Lesotho
Northern Cape
Eastern Cape
Biological Sciences
Earth Sciences
Industrial Biotechnology and Food Sciences
Mechanical and Industrial Engineering
Civil Engineering
Chemical and Process Engineering
Electrical and Electronic Engineering
Clinical Sciences
Medicine
Human Movement and Sport Science
Public Health and Health Services
Medical Biochemistry and Clinical Chemistry
Medical Microbiology
Immunology
Western Cape
N
Kilometers
0
200
400
600

Figure 4

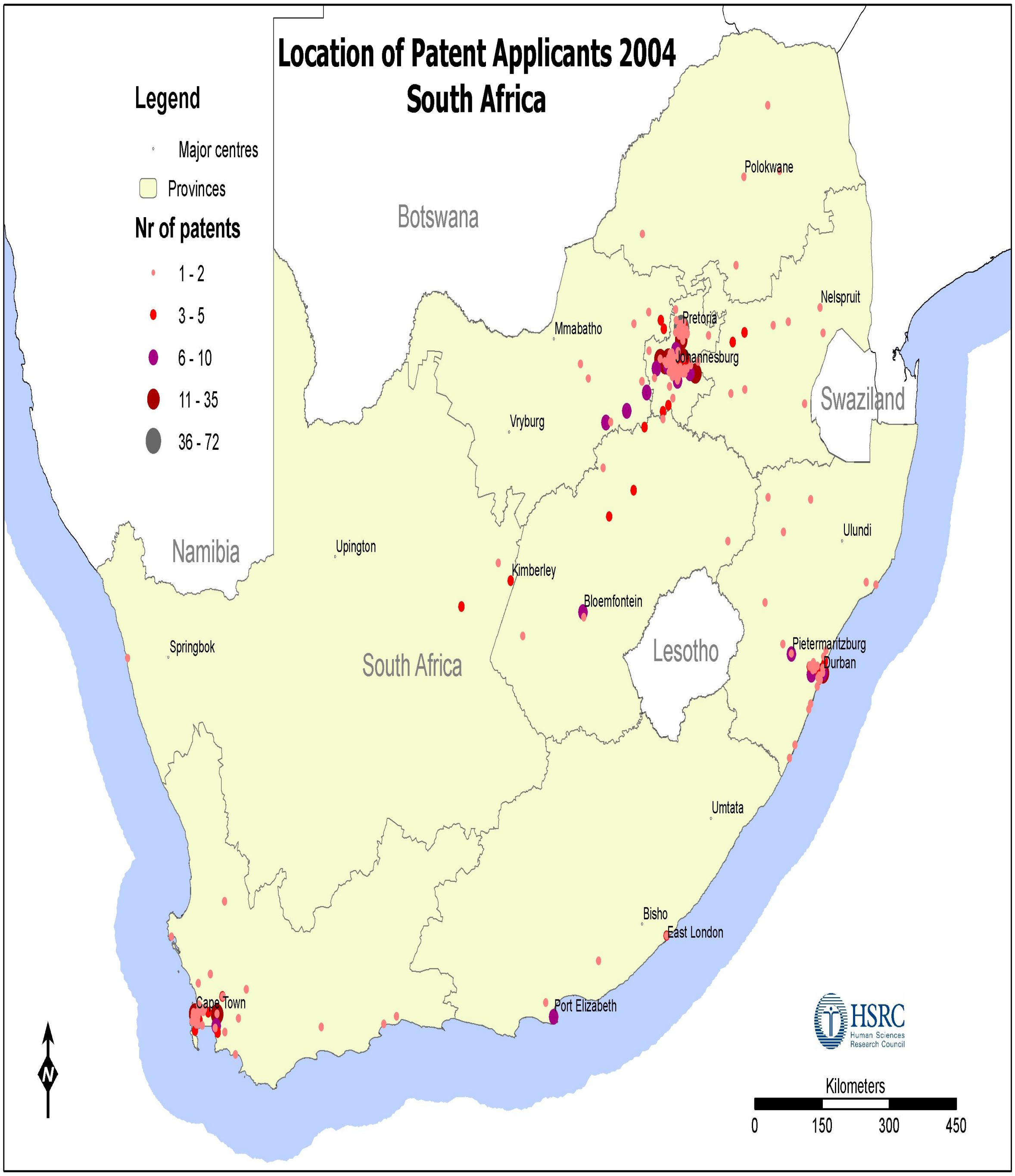
Location of Patent Applicants 2004
South Africa
Legend
Major centres
Provinces
Nr of patents
1 - 2
3 - 5
6 - 10
11 - 35
36 - 72
Botswana
Namibia
South Africa
Lesotho
Swaziland
Polokwane
Nelspruit
Pretoria
Johannesburg
Mmabatho
Vryburg
Upington
Kimberley
Bloemfontein
Springbok
Ulundi
Pietermaritzburg
Durban
Umtata
Bisho
East London
Port Elizabeth
Cape Town
N
HSRC
Human Sciences Research Council
Kilometers
0
150
300
450

Figure 5

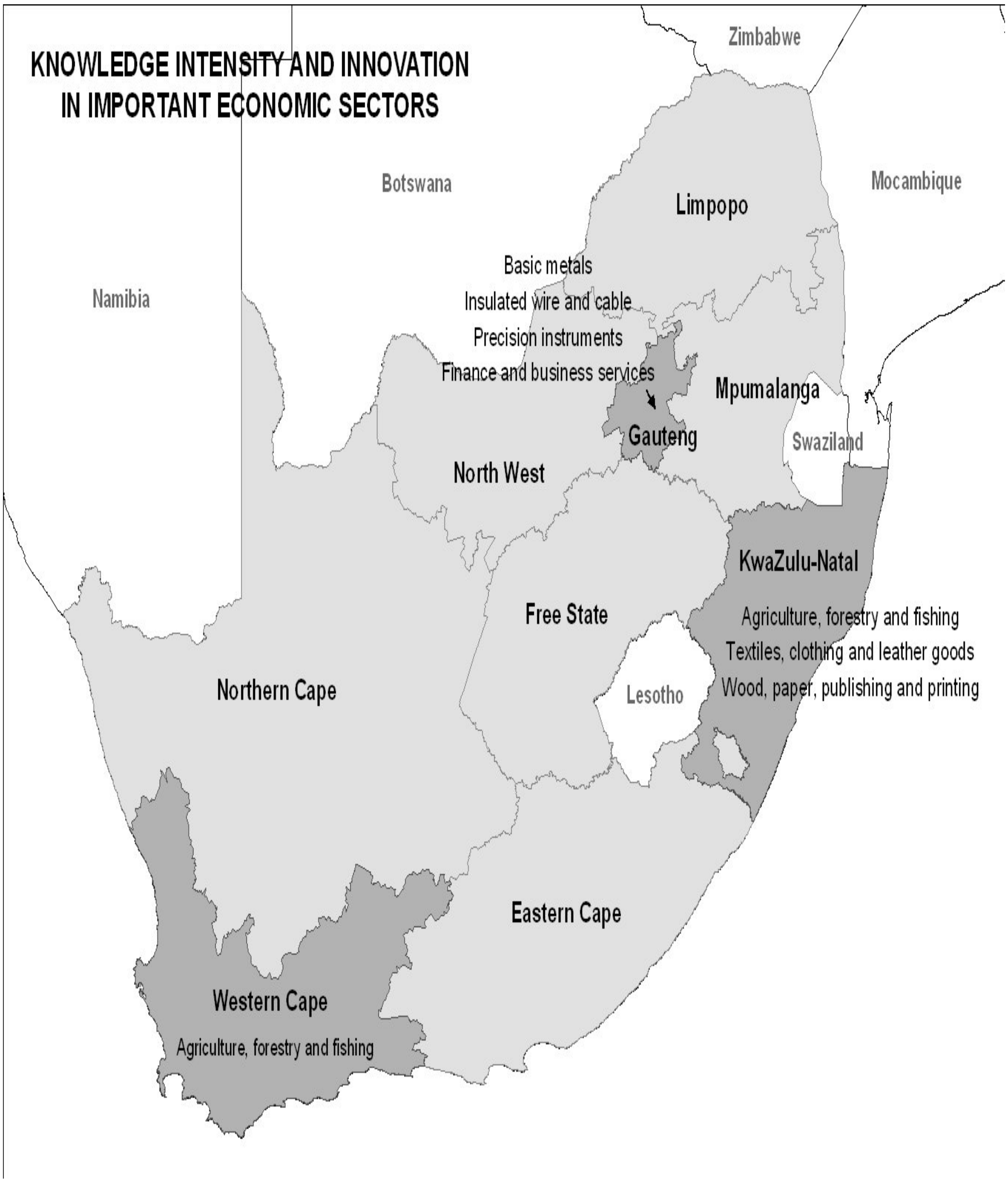
KNOWLEDGE INTENSITY AND INNOVATION
IN IMPORTANT ECONOMIC SECTORS
Zimbabwe
Botswana
Mocambique
Limpopo
Namibia
Basic metals
Insulated wire and cable
Precision instruments
Finance and business services
Mpumalanga
Gauteng
Swaziland
North West
KwaZulu-Natal
Free State
Agriculture, forestry and fishing
Textiles, clothing and leather goods
Wood, paper, publishing and printing
Lesotho
Northern Cape
Eastern Cape
Western Cape
Agriculture, forestry and fishing

Table 1
Correspondences of specialisations in industrial activity, R&D investments, and patent applications or use

Industrial activity	R&D investments	Patents: IOM	Patents: SOU
Gauteng			
Metals, metal products, machinery and equipment	Basic metals	Basic metals	Basic metals
Electrical machinery and appliances	Insulated wire and cable	Insulated wire and cable	
Radio, TV, instruments, watches and clocks	Medical appliances and instruments and appliances for measuring, checking, testing, navigating and other purposes; Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment; Optical instruments and photographic equipment	Radio, TV, instruments, watches and clocks	Radio, TV, instruments, watches and clocks

Industrial activity	R&D investments	Patents: IOM	Patents: SOU
KwaZulu-Natal			
Agriculture, forestry and fishing	Agriculture, forestry and fishing		Growing of crops; market gardening; horticulture
Textiles, clothing and leather goods	Textiles, clothing and leather goods	Tanning and dressing of leather	Tanning and dressing of leather
Wood, paper, publishing and printing	Wood and wood products	Paper and paper products Publishing and printing	
Western Cape			
Agriculture, forestry and fishing	Growing of crops; market gardening; horticulture	Agriculture, hunting, and related service activities	Growing of vegetables, horticultural specialties and nursery products Growing of fruit, nuts, beverage and spice crops Forestry, logging and related service activities

Figure 6

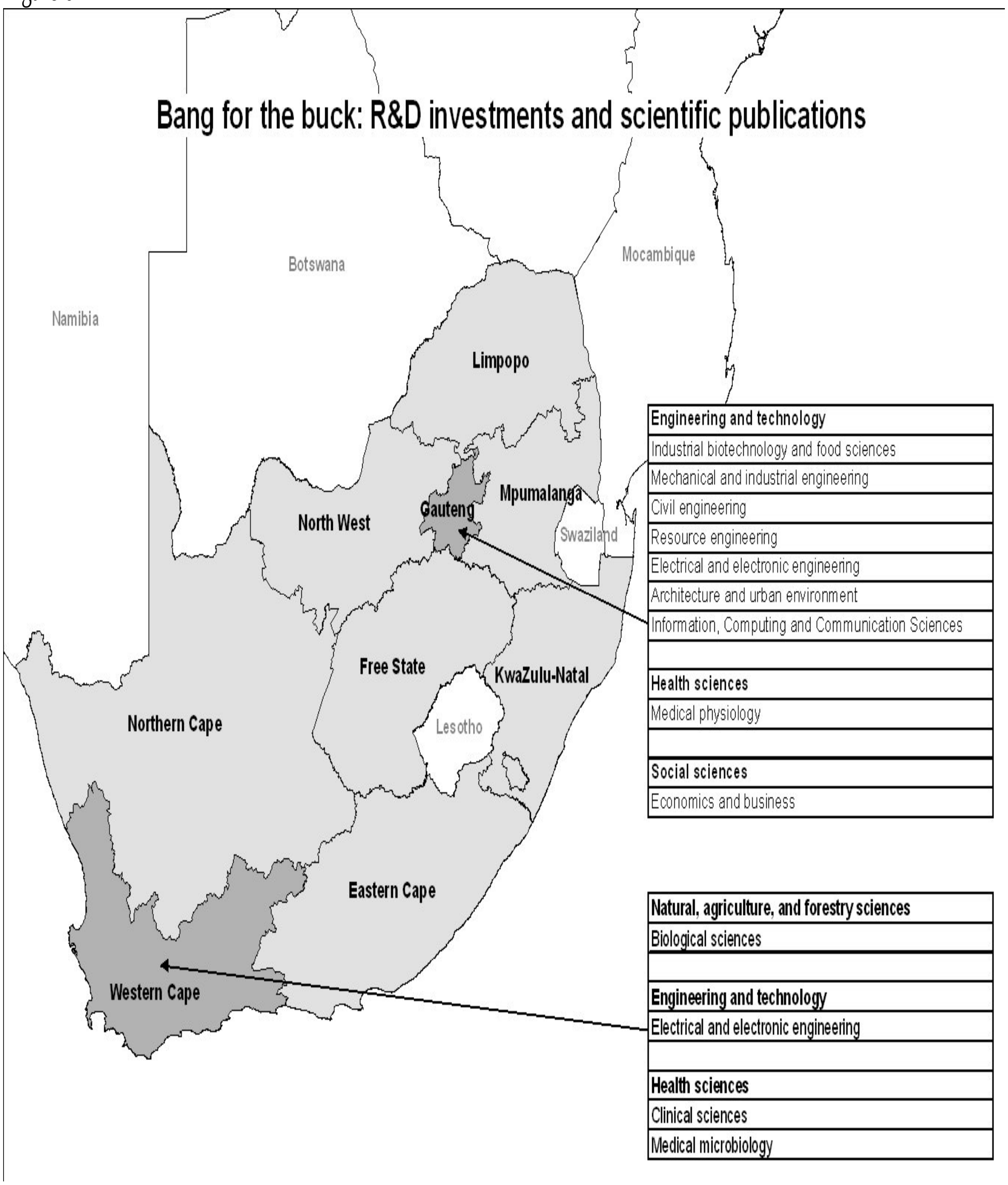
Bang for the buck: R&D investments and scientific publications
Botswana
Mocambique
Namibia
Limpopo
Mpumalanga
North West
Gauteng
Swaziland
Free State
KwaZulu-Natal
Lesotho
Northern Cape
Eastern Cape
Western Cape
Engineering and technology
Industrial biotechnology and food sciences
Mechanical and industrial engineering
Civil engineering
Resource engineering
Electrical and electronic engineering
Architecture and urban environment
Information, Computing and Communication Sciences
Health sciences
Medical physiology
Social sciences
Economics and business
Natural, agriculture, and forestry sciences
Biological sciences
Engineering and technology
Electrical and electronic engineering
Health sciences
Clinical sciences
Medical microbiology

Figure 7

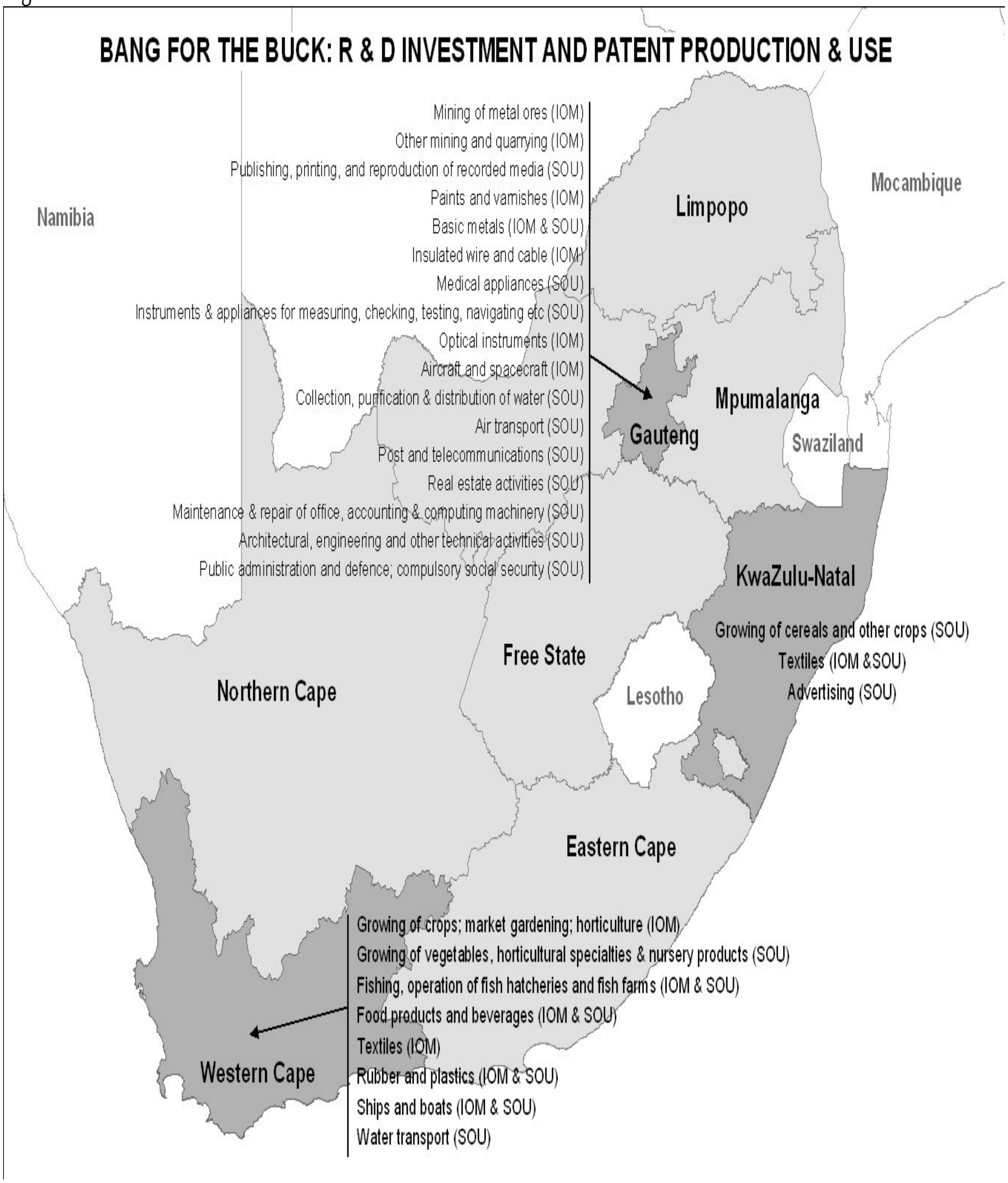
BANG FOR THE BUCK: R & D INVESTMENT AND PATENT PRODUCTION & USE
Mining of metal ores (IOM)
Other mining and quarrying (IOM)
Publishing, printing, and reproduction of recorded media (SOU)
Paints and varnishes (IOM)
Basic metals (IOM & SOU)
Insulated wire and cable (IOM)
Medical appliances (SOU)
Instruments & appliances for measuring, checking, testing, navigating etc (SOU)
Optical instruments (IOM)
Aircraft and spacecraft (IOM)
Collection, purification & distribution of water (SOU)
Air transport (SOU)
Post and telecommunications (SOU)
Real estate activities (SOU)
Maintenance & repair of office, accounting & computing machinery (SOU)
Architectural, engineering and other technical activities (SOU)
Public administration and defence; compulsory social security (SOU)
Namibia
Limpopo
Mocambique
Mpumalanga
Gauteng
Swaziland
KwaZulu-Natal
Growing of cereals and other crops (SOU)
Textiles (IOM &SOU)
Advertising (SOU)
Free State
Lesotho
Northern Cape
Eastern Cape
Growing of crops; market gardening; horticulture (IOM)
Growing of vegetables, horticultural specialties & nursery products (SOU)
Fishing, operation of fish hatcheries and fish farms (IOM & SOU)
Food products and beverages (IOM & SOU)
Textiles (IOM)
Rubber and plastics (IOM & SOU)
Ships and boats (IOM & SOU)
Water transport (SOU)
Western Cape

Table 2
Bang for the buck: R&D investments and patent production and use, 2004

R&D investments	Patents: IOM	Patents: SOU
Gauteng		
Mining of metal ores	√	
Other mining and quarrying	√	
Publishing, printing, and reproduction of recorded media		√
Paints and varnishes	√	
Basic metals		√
Insulated wire and cable	√	
Medical appliances		Manufacture of medical, precision and optical instruments, watches and clocks
Instruments and appliances for measuring, checking, testing, navigating and other purposes		√
Optical instruments	√	
Aircraft and spacecraft	√	
Collection, purification and distribution of water		Electricity, gas and water supply
Air transport		√

R&D investments	Patents: IOM	Patents: SOU
Post and telecommunications		√
Real estate activities		√
Maintenance and repair of office, accounting and computing machinery		√
Architectural, engineering and other technical activities		√
Public administration and defence; compulsory social security		√
KwaZulu-Natal		
Growing of cereals and other crops		Growing of crops; market gardening; horticulture
Textiles	Tanning of leather	Tanning of leather
Advertising		√
Western Cape		
Growing of crops; market gardening; horticulture	Agriculture	
Growing of vegetables, horticultural specialties and nursery products		√
Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing	√	√

R&D investments	Patents: IOM	Patents: SOU
Food products and beverages	√	√
Textiles	√	
Rubber and plastics	√	√
Other transport equipment	Ships and boats	Ships and boats
Water transport		√

Figure 8

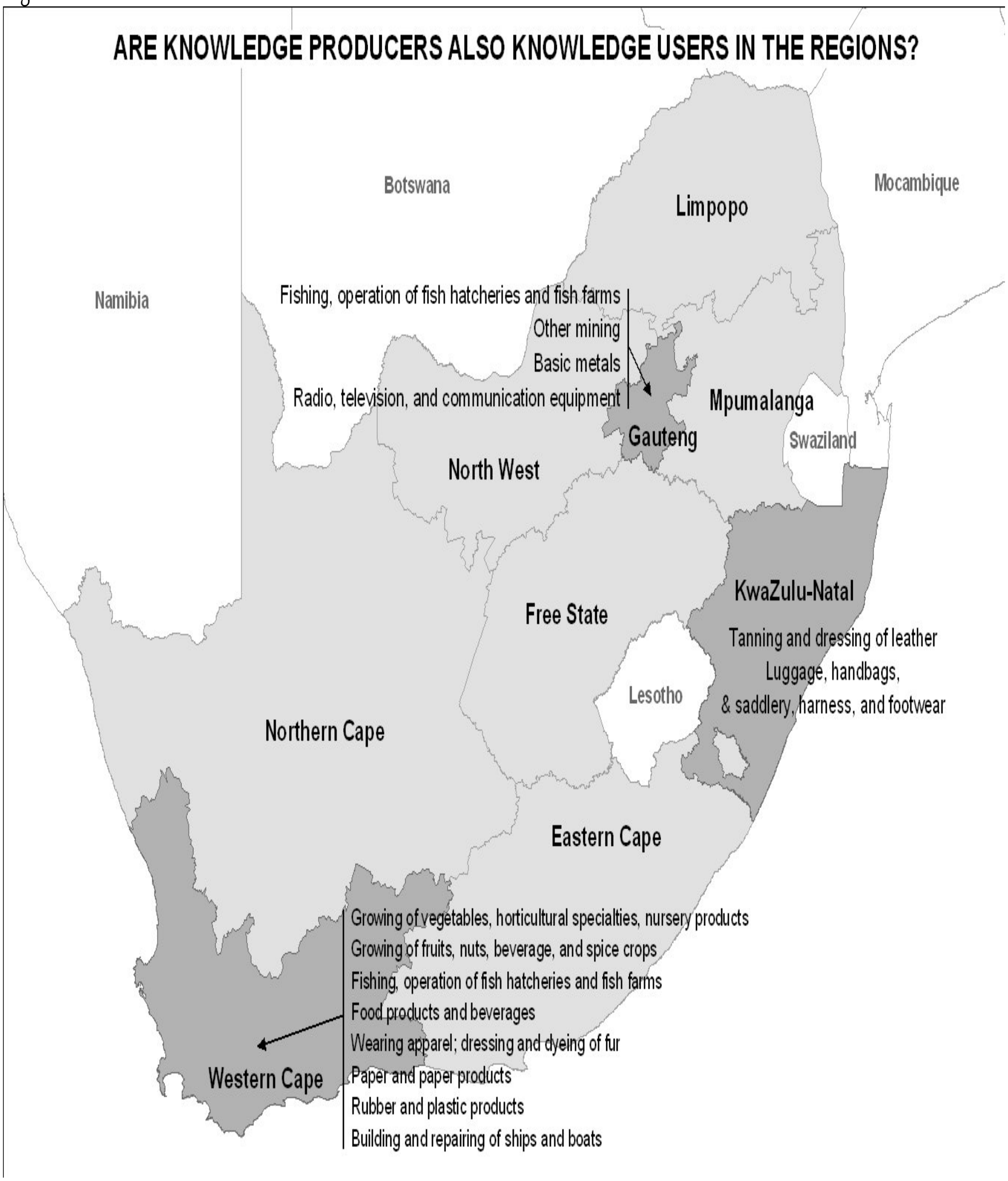
ARE KNOWLEDGE PRODUCERS ALSO KNOWLEDGE USERS IN THE REGIONS?
Botswana
Mocambique
Limpopo
Namibia
Fishing, operation of fish hatcheries and fish farms
Other mining
Basic metals
Radio, television, and communication equipment
Mpumalanga
Gauteng
Swaziland
North West
KwaZulu-Natal
Free State
Tanning and dressing of leather
Luggage, handbags,
& saddlery, harness, and footwear
Lesotho
Northern Cape
Eastern Cape
Growing of vegetables, horticultural specialties, nursery products
Growing of fruits, nuts, beverage, and spice crops
Fishing, operation of fish hatcheries and fish farms
Food products and beverages
Wearing apparel; dressing and dyeing of fur
Western Cape
Paper and paper products
Rubber and plastic products
Building and repairing of ships and boats

Table 3 -- South African provinces and the knowledge economy

	EC	GP	KZN	WC	SA
Performance indicators					
GDP(R), annual average growth, 1995-2007, %	3.1	4.2	3.7	4.2	3.7
Human Development Index 2003	0.62	0.73	0.63	0.77	0.67
Innovation system					
R&D per capita, Rand, 2005	104.4	811.8	162.5	674.7	315.7
SET PhDs/mil.pop., 2004	39.1	161.4	54.5	254.1	86.4
SET articles/mil.pop., 2007 (ISI)					
SET articles/mil.pop., 2004 (local)	66.0	263.0	75.0	473.0	144.0
USPTO patents/mil.pop., 2007	0.6	9.1	1.1	6.2	2.9
CIPRO patents/mil.pop. 2004	3.0	56.0	11.0	25.0	19.0
Education and human resources					
Adult literacy rate, %, age 15+, 2003	77.6	96.7	90.5	94.6	86.9
Secondary enrolment, %, tot. pop., 2003	9.0	7.0	10.0	7.4	9.2
Tertiary enrolment, % tot.pop., 2003	2.2	1.8	1.1	1.8	1.7
Information infrastructure					
Households with mobile phone, 2007, %	61.2	80.3	71.9	74.5	72.7
Households with computer, 2007, %	7.5	24.2	11.7	30.1	15.6
Households with internet access, 2007, %	3.2	11.7	5.5	16.3	7.2

Notes: EC = Eastern Cape, GP = Gauteng Province, KZN = KwaZulu-Natal, WC = Western Cape, SA = South Africa.
SET = Science, Engineering, and Technology, USPTO = US Patent and Trademark Office, CIPRO = Companies and
Intellectual Property Registration Office.

Sources: Quantec, UNDP (2003), DST (2006), HEMIS, HSRC, USPTO, CIPRO, Community Survey.

Table 4 -- South Africa's city-regions and the knowledge economy

	NMM	GGCR	eThekwini	Cape Town	SA
Performance indicators					
GDP(R), annual average growth, 1995-2007, %	3.5	3.9	3.8	4.3	3.7
GDP(R), annual average growth, 2002-2007, %	4.3	5.0	4.7	5.6	3.7
Human Development Index 2003	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
Innovation system					
R&D per capita, Rand, 2005	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
SET PhDs/mil.pop., 2004	110.0	124.6	111.5	309.1	86.4
SET articles/mil.pop., 2007 (ISI)					
SET articles/mil.pop., 2004 (local)	96.4	164.7	130.2	514.9	144.0
USPTO patents/mil.pop., 2007	2.7	6.3	1.1	6.2	2.9
CIPRO patents/mil.pop. 2004					
Education and human resources					
Adult literacy rate, %, age 15+, 2003					
Secondary attainment, %, tot. pop., 2001	13.6	17.0	13.4	18.9	10.7
Tertiary attainment, % tot.pop., 2001	3.0	4.5	3.1	4.5	2.8
Employed: high skilled, 2006, %	13.0	14.0	13.0	13.0	13.0
Employed: skilled, 2006, %	44.0	44.0	44.0	44.0	43.0
Employed: unskilled, 2006, %	43.0	43.0	43.0	43.0	44.0
Information infrastructure					
Households with mobile phone, 2007, %	64.3	79.7	74.7	75.8	72.7
Households with computer, 2007, %	19.9	21.9	17.9	32.1	15.6
Households with internet access, 2007, %	8.0	10.3	8.5	17.3	7.2
Socioeconomic indicators					
Dependency ratio	44.5	43.5	47.9	46.3	57.3
EAP, annual average growth, 2001-2007, %	0.8	2.0	1.8	3.0	0.8
Employment growth, 2001-2006	0.8	2.4	1.3	0.7	
Global networks		*Joburg*	*Durban*	*Cape Town*	
Total connectivities	*n/a*	26232	9592	15126	*n/a*
Share in total connectivities	*n/a*	0.006	0.002	0.004	*n/a*
Share in highest possible connectivities	*n/a*	0.414	0.151	0.239	*n/a*

Notes: see Table 3. EAP = economically active population. Connectivities in global networks refer to the
presence of and linkages between business service firms among 315 cities in the world in 2000.

The data were produced by P.J. Taylor and constitute Data Set 12 of the GaWC Study Group and Network
(http://www.lboro.ac.uk/gawc/) publication of inter-city data.
Sources: see Table 3; for more on global network data, see Taylor (2001).